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Evaluation of a New Zealand Tremadocian trilobite

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Abstract

Dionide hectori Reed, 1926, is shown on the basis of new collections from the type area in New Zealand to be a Tremadocian ceratopygide close to Hysterolenus. The species was placed in Taihungshania by Kobayashi (1941). It was provisionally retained in the Taihungshaniidae by Lu (1975) who made hectori type species of a new genus Hectoria (non Hectoria Trechmann, 1918). Ruapyge nom.nov. is proposed here for the reception of hectori. The original length/width ratio is determined by Wellman's method, with little consistency in results. Data from the strain ellipses constructed by Wellman's method are then used to calculate values for the attitude of the line of no finite longitudinal strain. The values obtained graphically do not agree with those derived from a formula given by Ramsay (1967); this contradictory situation is in need of explanation.

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Evaluation of a New Zealand Tremadocian trilobite

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(Plates 1–2)

Summary. *Dionide hectori* Reed, 1926, is shown on the basis of new collections from the type area in New Zealand to be a Tremadocian ceratopygide close to *Hysterolenus*. The species was placed in *Taihungshania* by Kobayashi (1941). It was provisionally retained in the Taihungshaniidae by Lu (1975) who made *hectori* type species of a new genus *Hectoria* (non *Hectoria* Trechmann, 1918). *Ruapyge* nom.nov. is proposed here for the reception of *hectori*. The original length/width ratio is determined by Wellman's method, with little consistency in results. Data from the strain ellipses constructed by Wellman's method are then used to calculate values for the attitude of the line of no finite longitudinal strain. The values obtained graphically do not agree with those derived from a formula given by Ramsay (1967); this contradictory situation is in need of explanation.

1. Introduction

Lower Palaeozoic shelly fossils in New Zealand are generally sparse and poorly preserved as a result of their tectonic history. Ordovician trilobites are not excepted from this fate, and to date only three species have been described and another listed.

Two species (*Dionide hectori* and *Ogygites collingwoodensis*) were described by Reed (1926). A further species, *Incaia bishopi* Hughes & Wright, 1970, occurs with *Ogygites collingwoodensis* and graptolites determined by Dr R. A. Cooper as Caradocian. Skwarko (1962) listed an occurrence of *Triarthrus*.

New collections of abundant and, compared with Reed's original material, relatively well preserved trilobites, including *Dionide hectori* Reed, have permitted a reassessment of *hectori* and the age and affinities of the entire fauna. Reed (1926) placed *hectori* in *Dionide* and suggested a broad Ordovician age for the poorly preserved material at his disposal. Kobayashi (1941) placed *hectori* in *Taihungshania* and attributed an Arenigian age to the occurrence.

This latter generic assignment and the contingent age determination have become entrenched in the literature (Grindley, 1961; Whittington, 1966; Dean, 1967; Kobayashi, 1971; Ross, 1975; but see Whittington & Hughes, 1972, p. 245). Attention has previously been drawn to the erroneous nature of this assignment (Wright, 1968; Whittington, 1973; Lu, 1975). Poor preservation of much of the material from the *hectori* faunas in New Zealand makes it impossible to disprove the presence there of *Taihungshania*, but certainly *hectori* cannot belong to that genus. Lu (1975, p. 339) erected for *hectori* a new monospecific genus, *Hectoria*, which he provisionally placed in the Taihungshaniidae. However, the affinities of *hectori* with the Ceratopygidae are quite clear. In fact the species is sufficiently well known that important aspects of the morphology of the family emerge. Finally it should be noted that the name *Hectoria* was originally used by Trechmann (1918) for a New Zealand Triassic brachiopod. Dr Lu (pers. comm.) kindly permits me to introduce the new name *Ruapyge* for Reed's species.

2. Stratigraphy and age

Recent mapping (Coleman, 1977) in the Mount Patriarch area of the South Island of New Zealand has led to the recognition of a sequence which, on the basis of new collections, probably spans the Cambrian–Ordovician boundary. The sequence, as interpreted by Coleman (1977), is:

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Summit Limestone	295 m+ (Cooper & Druce, 1975)
Patriarch Formation	400 m
Anatoki Formation	1000 m+ (base not seen in this area)

Ruapyge hectori is found at a number of localities restricted to the Patriarch Formation (Fig. 1), which has as yet yielded no conodonts. The *R. hectori* trilobite fauna is Tremadocian in age, as indicated by the eulomide and shumardiide trilobites, which occur *with* the stratigraphically lowest *R. hectori*. The above groups (accepting *R. hectori* as a ceratopygide) are not known

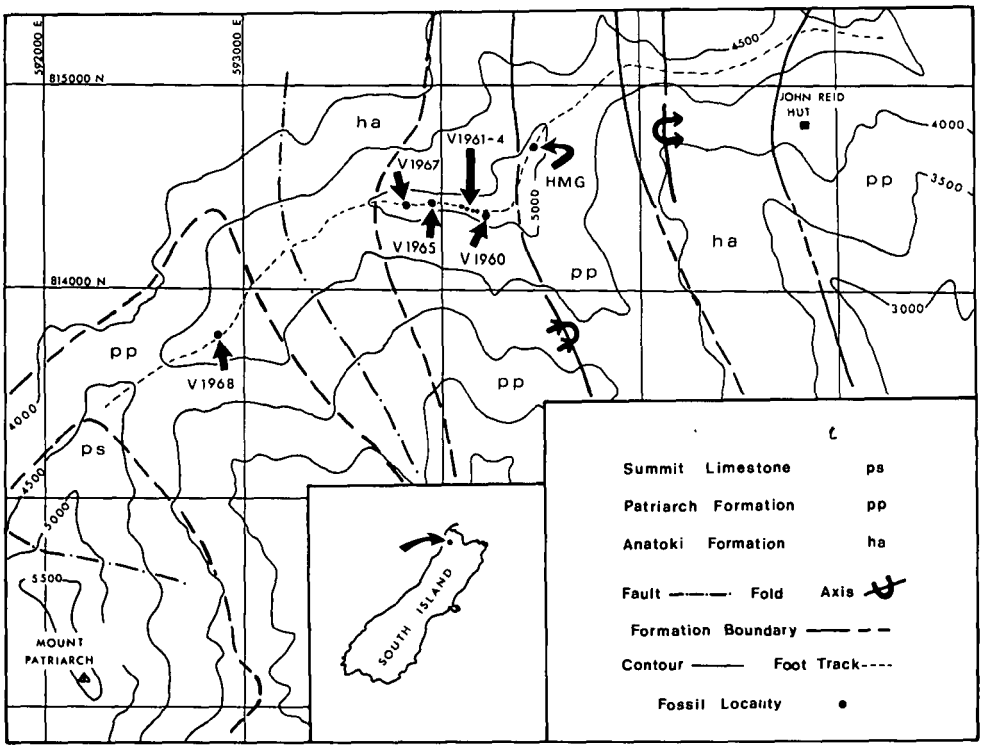

Figure 1. Geological sketch map of the Mount Patriarch area, South Island, New Zealand, after Coleman (1977), showing fossil localities. Grid lines are at 1000 yard (914 m) intervals; contour intervals are 1000 ft (305 m). Fossil locality HMG is the probable type locality.

together traditionally below the Tremadocian, nor are ceratopygides considered normally to range above the Tremadocian. *L.* (*Lotagnostus*), also a member of the fauna, is not found above the Tremadocian. Further evidence comes from Copper & Druce (1975, p. 569), who assigned an 'earliest Arenigian' age to a conodont fauna from the lower part of the Summit Limestone.

3. Systematic palaeontology

Specimens whose number is prefixed VA are in the type trilobite collections of the Department of Geology, Victoria University of Wellington, New Zealand; specimens prefixed AR are held by the New Zealand Geological Survey, Lower Hutt, New Zealand. Suffixes *a* and *b* refer to counterparts.

Class: Trilobita
Order: Ptychopariida

Suborder: Asaphina
Superfamily: Ceratopygacea
Family: Ceratopygidae
Genus: *Ruapyge* nom.nov.
1975 *Hectoria* Lu, pp. 141, 339 (non *Hectoria* Trechmann, 1918, p. 233)
Type species: *Dionide hectori* Reed, 1926

Diagnosis (new). Ceratopygidae with very long genal and pygidial spines. Glabella subrectangular to slightly tapering forwards, with rounded anterior; 3 pairs of glabellar furrows, with a glabellar node behind mid-length of posterior furrow; occipital furrow shallow medially, being shallow and sharply incised across-axis. Preglabellar field concave, as is pygidial border. In front of probably holochroal eyes, sutures divergent. Prosopon of very fine granules. Six thoracic segments. Up to eight pygidial axial rings, and six pleural ribs.

Remarks. R. hectori was initially placed in *Dionide* by Reed (1926) even though he noted the dissimilarity of *hectori* to the type species of *Dionide*, *D. formosa* Barrande. The generic assignment seems to have been based on Reed's (1926, pp. 313–14) comparison of *hectori* with *Dionide richardsoni* Reed and *D. holdoni* Raymond, both of which, however, lack pygidial spines (Reed, 1926, p. 313). Kobayashi (1941) re-examined Reed's material and concluded that *hectori* should be placed in *Taihungshania* Sun, 1931 (which has been considered a senior subjective synonym of *Miquelina* Thoral, 1935). The type species of *Taihungshania* is *T. shui* (Sun, 1931), known originally from pygidia, as well as a thorax showing seven segments. The pygidia of *Taihungshania* are spinose but differ from the pygidium of *R. hectori*. As the generic name *Hectoria* is preoccupied, I propose the new name *Ruapyge* for *hectori*.

All major features of *R. hectori* substantiate its assignment to the Ceratopygidae. The greatest morphological resemblance is with *Hysterolenus* and perhaps *Pseudohysterolenus*. After Harrington *et al.* (1959, 0363) *Hysterolenus* has 4 glabellar furrows and 8–10 pygidial axial segments. *Pseudohysterolenus* is poorly known (Harrington & Leanza, 1957, p. 191, figs 98, 99) and although the glabella is similar to that of *R. hectori*, the posterolateral limbs of the cranidium are relatively short (tr.) and the pygidium is dissimilar from that of *R. hectori*. *Bicornipyge* Lisogor, 1961, from Kazakhstan differs from *Ruapyge* principally in the cephalic border and, in the pygidium, the sparse (4–5) axial rings and pleurae concentrated anteriorly (Lisogor, 1961, pl. 2, figs 14–17; pl. 3, figs 1–4). In this aspect of (pygidial) morphology *Bicornipyge* resembles *Onychopyge* Harrington, 1938. *Diceratopyge* (Troedsson, 1937) differs mainly in that it lacks glabellar furrows.

In addition to *hectori*, *Ruapyge* may include *Hysterolenus oblongus* Lisogor, 1961, from the Tremadocian Kendiktassy Horizon of Southern Kazakhstan. Lisogor reported (1961, p. 70) four pairs of glabellar furrows but only three are visible (Lisogor, 1961, pl. 2, figs 1, 2, 4) with certainty. In other respects, including the six thoracic segments and six pygidial axial rings, *H. oblongus* is indeed close to *R. hectori*. However, the eye ridges of *H. oblongus* may have considerable significance. *Hysterolenus asiaticus* Lu *et al.* (1965, p. 552, pl. 116, figs 5, 6) would appear possibly congeneric with *R. hectori*, except for the four glabellar furrows reported by them. Features which probably indicate at least specific difference appear to be the concavity of cephalic and pygidial margins, the relative size of the eyes and the detailed course of the facial sutures. On the basis of the above, *Ruapyge* occurs in New Zealand and possibly in Kazakhstan (Lisogor, 1961) and China (Lu *et al.* 1965).

The name of *Ruapyge* (feminine gender) is based on the Maori word 'rua' for the numeral two and the suffix 'pyge' (rump), referring to the two prominent tail spines.

Ruapyge hectori (Reed, 1926)

Plate 1, figs *a–k*, ?figs *l*, *m*; Plate 2, figs *a–l*; Fig. 2.

v* 1926 *Dionide hectori* Reed, sp.nov., p. 312; pl. 17, fig. 2c (only).
1940 *Taihungshania hectori* (Reed); Kobayashi, p. 195, pl. xx, figs 1,1[1].
1975 *Hectoria hectori* (Reed); Lu, pp. 339–40.

Etymology. The specific name is a patronym for Dr (later Sir) James Hector, first Director of the Colonial Museum and Geological Survey of New Zealand.

Type stratum. Patriarch Formation (see below).

Type locality. Two fossil localities are shown for this area by Henderson, Macpherson & Grange (1959). As ceratopygides are very rare at the western locality which was probably close to V1968 (grid reference S19-928138), the other locality (HMG on fig. 1; grid reference S19-928138) appears to be the source of the type specimen. I have not recollected at this locality, but localities V1963, 1964, 1965 on the western limb of the syncline probably straddle this stratigraphic level. Equivalent strata immediately NE of Mount Patriarch are very poorly exposed in a saddle. Scraps of trilobites are often evident but the pervasive cleavage often precludes collection of identifiable material. The localities from which I have collected identifiable material are shown in Figure 1, with the prefix V.

Type material. The lectotype here selected is AR 667; this was figured by Reed (1926), pl. 17, fig. 2c). Kobayashi (1941, p. 198) stated: 'I selected the first and second [specimens] as cotypes of the species and the third as well as the fourth specimen and probably one in fig. 2a in Reed's plate may be referred to it.' Thus he selected the specimens AR 667 (Reed, 1926, pl. 27, fig. 2c; Kobayashi, 1941, pl. xx, fig. 1.1[1]) and AR 668 (Reed, 1926, pl. 27, fig. 2d; Kobayashi, 1941, pl. xx, fig. 2.2[1]) as cotypes. The most meaningful procedure seems to be to select one of these as lectotype; fortunately the first-mentioned specimen (AR 667) is a well-preserved pygidium.

Kobayashi (1941, p. 197) expressed doubt about placing the specimen AR 670 (Reed, 1926, pl. 27, fig. 2f) in *hectori*, and I agree with this. As discussed elsewhere, much fossil material from the Mount Patriarch area is indeterminable. On the basis of more than six thoracic segments, I would exclude from *R. hectori* much otherwise unidentifiable material. Apart from the lectotype no other specimen from Reed's (1926) original collection can be said to belong definitely to *R. hectori*. In addition to the lectotype (AR 667) only one specimen (AR 665; Reed, 1926, pl. 17, fig. 2a) can even be said to be probably *R. hectori*. In fact preservation is so poor that it is impossible even to say that the bulk of the material is not *R. hectori*.

In addition to the type material, a single pygidium referable to *R. hectori* was collected by the original workers and is held by the N.Z.G.S. The accompanying locality data refer to two separate localities – one is 'Ridge at head of Gibbs Creek' (i.e. a locality compatible with the present material). The other ('Wright Creek') is on the SW side of the Wangapeka River (that is, the *opposite* side to all known *R. hectori* localities); I consider this is erroneous.

A serious argument could be advanced for treating Reed's poorly preserved type material as inadequate, rendering *R. hectori* an unrecognizable taxon. However, as the fauna of the Patriarch Formation is known to contain only one species of ceratopygide, there is little real chance of confusion. Further, the name is entrenched in New Zealand geological literature and has therefore been retained here. Nevertheless, certain morphological features (e.g. exact shape of glabella) are only approximately known.

Diagnosis. see generic diagnosis.

Description. Cephalon elongate semi-elliptical to semicircular, with broad concave border and acute genal angles with spines reaching to about mid-length of pygidium. Preglabellar field weakly convex immediately in front of eyes, becoming concave laterally and anteriorly; frontally no convexity visible; narrow convex rim; bearing 15–20 evenly spaced terrace lines on doublure. Glabella moderately convex (tr.), approximately parallel-sided with very slight median waisting

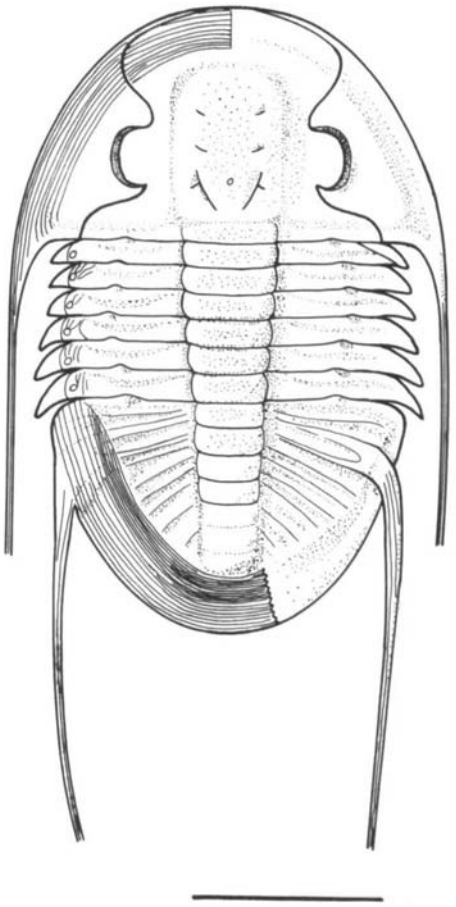

Figure 2. Diagrammatic reconstruction of *Ruapyge hectori* (Reed, 1926) based mostly on VA147 and VA151a, b, showing dorsal surface on right and internal mould on left. Relative dimensions are only approximate as are the number and detail of terrace lines. Bar scale 1 cm approximately.

and anterior expansion, with rounded sub-rectangular anterior shape. Axial furrows narrow and sharp in front of eyes, shallow and rounded adjacent to eyes and deep behind eyes; weak fossulae anteriorly are shallow and semicircular in plan. Glabella reaches about seven-tenths of cephalic length and about one-sixth of cephalic width. Three pairs of glabellar furrows; the largest pair occupies most of posterior half of glabella. *1p* is directed inwards and backwards, anterior one-third tending to be almost sagittal; at point of inflexion there is a suggestion (probably at least accentuated by deformation) of a short laterally directed fork. *2p* and *3p* are slightly backwards and inwards-directed, expanding and shallowing outwards, almost reaching axial furrow; *2p* lies near mid-length of glabella; no furrows cross mid-line of glabella which bears

a low median node near mid-length of *lp*. Occipital furrows strong laterally, narrow and shallow over axis. Palpebral lobes large, elevated and semi-oval (sag.), symmetrical about mid-length of glabella. Part of one lobe on a single specimen (VA 147) shows about 30 small circular depressions (lenses), representing about one-third of the eye area and arranged in about six horizontal rows. Only smooth external moulds of eyes of *hectori* are known, suggesting the holochroal condition. Facial suture cuts posterior border of cephalon half-way from axial furrow to outer edge of cephalon; anteriorly it trends axially at a high angle, not reaching steep outer slope of axial furrow describing prominent semi-oval around eyes; anterior branches diverge, initially at 75–90° (apparently less in juveniles), curving sharply so as to meet rim of cephalon medially of extension of axial furrows; anterior branches meet at obtuse angle, just on ventral surface of rim. Librigenae with gently convex cheeks, depressed below glabella; narrow doublure widest (tr.) at posterior end of cephalon; low rounded posterior border furrow on fixigena swings almost anteriorly on librigena. Genal spine very long, rounded in section and bearing about 15 terrace lines around spine. Hypostoma not known with certainty.

Thorax with six segments; axis convex (tr.) and slightly tapering posteriorly (more rapidly than pygidial axis). Axial rings are simple, with a slightly flattened crest tilted anteriorly. Pleural regions subdivided into two areas by an outwardly convex imaginary line running from well inside posterior trace of facial suture to mid-width of pleural region of pygidium. 'Inner area' delineated axially by deep axial furrow; flat to slightly convex (tr.), gently concave (exsag.) and tilted axially; steeply inclined outer region defined along inner edge by (presumably) line of fulcral processes and sockets. Pleural furrow starts anteriorly, expands and trends slightly posteriorly, forming a trough over most of width (exsag.) of pleurae; curves slightly anteriorly to inflection point, on both sides of which furrow is deeply depressed but rapidly weakens outwards. 'Outer area' consists of pleural extremities which become narrower (exsag.) over outer half; by mid-width (tr.) in this area, pleural furrows are very weak and prominent panderian processes occur on doublure very near end of furrow, near posterior edge of pleura. Pleural extremities progressively more curved posteriorly, tending to be acute; doublure extends about half-way up 'outer area', bearing a few terrace lines on ventral surface of segment. Anterior segment bears prominent facet.

Pygidium transversely semi-oval (longitudinally semi-oval in some deformed specimens), gently convex (tr.) with a moderately to highly convex axis (tr.). Anterior edge transverse to about mid-width of pleural region where a sharp postero-lateral deflection is located outside a marked elevation in border; antero-lateral extremities sharply rounded, at just less than 90°; facets developed on outer portion of this postero-lateral region. Axis anteriorly about half as wide as a pleural region, slightly tapering posteriorly, having eight or fewer axial rings (anterior two generally prominent) and a low blunt semi-circular terminal region with steep posterior face down to wide, gently concave border with narrow convex rim; axial furrows narrow and well defined except behind posterior axial extremity; axis and pleural regions moderately convex (tr.). About 4 (rarely 5–6) pleurae, apparently arising opposite axial rings (at least in case of anterior two); pleural furrows run length of pleurae, laterally becoming more anteriorly placed, wider and more rounded. Interpleural furrows deep, rounded and widening (sag.) laterally. Anterior pleura curved posteriorly. Spine formed by posterior band of first pleura and anterior band of second pleura; reaches length in excess of pygidial length, normally posterior ends curving medially; cross section probably tubular; around it are about 15–20 terrace lines. Doublure as wide anteriorly as the concave border; slightly narrower antero-laterally, extending as far as inner slope of border and bearing about 15–20 terrace lines posteriorly.

Terrace lines are prominent around both genal and pygidial spines but elsewhere are present only on the doublure. On the pygidial doublure there are about 15 lines medially, being more distantly spaced peripherally; antero-laterally there are far fewer lines – about six in number – all distantly spaced, the longitudinal fate of the closely spaced lines being unknown due to poor preservation.

Ontogeny. Useful juvenile materials are available from localities V1963 and V1965. These are mostly cranidia and pygidia. Juvenile cranidia show a more angular marginal furrow and rim and a more fusiform glabella in plan. Pygidia show, in particular, a marked increase in the relative width of the axis, initially being only one-eighth total pygidial width (VA174, VA175); pleurae are initially noticeably straight and spines arise more posteriorly (VA180, VA174) at first; spines apparently not present in some of smallest specimens; posterior deflection of the antero-lateral region quite marked in some specimens (VA166, VA168, VA188); relative width of border increases with size.

Remarks. A single internal mould (VA147; Pl. 1 *b*) shows an incomplete visual surface bearing ventral moulds of lenses. I know of no other ceratopygide for which this feature has been reported, although holochroal eyes are known from other superfamilies of the Asaphina (Clarkson, 1975, fig. 1). The eye surface seen in all external moulds is smooth and suggests that the eye had a continuous cornea; thus a holochroal organ is indicated.

The distribution of terrace lines in *R. hectori* is not like the general condition described by Miller (1975, p. 165) in that the spacing of the lines on the pygidial doublure is not constant although on the cephalic doublure it appears constant. The Scandinavian species *Pseudasaphus aciculatus* (Jaanusson, 1953, pl. 4, fig. 4), *Pseudobasilicus? brachyrachis* (Jaanusson, 1953, pl. 9, fig. 2) and *Ogygiocaris s. striolata* (Henningsmoen, 1960, pl. 3, fig. 10) also show similar differences in pygidial terrace line spacing. *P. aciculatus* is further interesting in that the innermost (i.e. closely spaced) lines terminate anteriorly against the inner edge of the doublure.

Distribution. R. hectori is known from a number of localities in the area, namely V1960, V1961, V1963 (abundant) 1964, V1965 (abundant), V1967 (single doubtful specimen), V1968 (single tail); Dr R. A. Cooper and A. C. Coleman (pers. comm.) have collected further material from elsewhere in the Patriarch Formation. Grid references (1963 Tadmor Sheet S19) are: V1960–4, 942144–941144; V1965, 939144; V1967, 938144; V1968, 928138. Localities bearing the prefix V refer to localities registered in the Department of Geology, Victoria University of Wellington, New Zealand.

4. Discussion

4.a. Dimensions

Grindley (1961), Cooper (1975) and Coleman (1977) commented on the severity of deformation in the region. This is relevant here in that the original dimensions of the deformed trilobites are uncertain.

In this highly deformed material 'broad' and 'elongate' specimens of *R. hectori* occur. The maximum observed length for a complete specimen (excluding spines) is about 31 mm when the width is 14.5 mm; this is clearly an 'elongate' and mature specimen. The largest 'broad' specimen is 16.5 mm long and 22.5 mm wide. In both specimens and other deformed material the ratios of the lengths of cephalon (omitting genal spines) to thorax to pygidium (omitting spines) is *about* 2:1.5:2. Hirsinger (1976) studied some *R. hectori* material and in his figure 3 B ii gave an undeformed outline comparable with that given here in Figure 2.

It should be noted that reconstructions of relative dimensions are fraught with problems. Accurate measurement of moulds and consistent measurement of exactly the same morphological feature (i.e. the same structural point on structures of different curvatures) is difficult. The brittle fracturing and telescoping of tergites add further complications. However, in all cases measurements have been taken parallel to the originally mutually perpendicular lines.

Using Wellman's (1962) method, strain ellipses have been constructed for suitable bedding surfaces from which the relative elongation (parallel to the major axis of the ellipse) has been

obtained. From these figures it is theoretically possible after Wellman (1962) to calculate the original relative dimensions of symmetrical specimens. *W/L* ratios so calculated are shown on Table 1. As was concluded in a similar previous study (Hughes & Wright, 1970), results from

Table 1. List of slabs used in calculations of original width/length (W/L) ratio by Wellman's (1962) method, and details of symmetrical specimens used

Slab no.	Specimen	Ratio of lengths of axes of strain ellipse	Deformed W/L	'Original' W/L
1	Cranidium	1.57	2.43 (broad)	1.55
	Pygidium		1.28 (elongate)	1.92
2	Cranidium	1.38	0.83 (elongate)	1.15
3	Pygidium	1.38	2.31 (broad)	1.73
4	None suitable	1.51		
5	Pygidium	1.48	1.80 (broad)	1.22
6	Pygidium	1.35	2.67 (broad)	1.98
	Pygidium		2.88 (broad)	2.14
7	None suitable	1.38		
8	Pygidium	1.43	3.55 (elongate)	2.45
			3.25 (elongate)	2.24
9	Pygidium	1.69	1.44 (broad)	2.44

different bedding surfaces are not in good agreement. In an effort to understand and possibly check these results, attempts were made to determine the attitudes of the lines of no finite longitudinal strain (Ramsay, 1967) which would permit the identification of theoretically unstrained dimensions of suitably orientated fossils.

Ramsay (1967) gave two methods – one graphical (Ramsay, 1967, fig. 3–12) and the other based on his formula 3–33a (Ramsay, 1967, p. 66) – for the determination of θ' which defines the attitude of the line of no finite longitudinal strain. In all examples so treated, the angle determined graphically is consistently higher than that determined from the formula, by 7–13° (see Table 2).

Table 2. Values of θ' obtained by two different methods for 9 slabs

Slab no.	Calculated	Graphical
1	55.29°	66°
2, 3, 7	50.5°	57.50°
4	54.76°	65.50°
5	53.42°	63°
6	49.62°	58°
8	52.8°	62°
9	57.43°	70°

Ramsay (1967, p. 67) implied that for certain values of λ_1 and λ_2 there may be no unstrained lines in a strain ellipse. However, in the present study λ_1 and λ_2 were calculated as the squares of the half-lengths of the major and minor diameters of the strain ellipse (Ramsay, figs 3–8). As the absolute size of the ellipse is a matter of convenience in the Wellman method, it does seem possible to adjust these values of λ_1 and λ_2 so as to give a real result.

The above discussion is intended to outline problems in treating tectonically deformed fossils in some realistic quantitative fashion. It is hoped by this to stimulate some positive discussion.

4.b. Depositional environment

The nature of the preservation suggests that the *R. hectori* fauna was preserved in a low energy environment. This is consistent with what little is known of the palaeo-environment in the region. The Anatoki Formation, which underlies the Patriarch Formation, is considered by Coleman (pers. comm.) to be largely a proximal turbidite sequence. The Summit Limestone, which overlies the Patriarch Formation, has yielded trilobites, brachiopods and rare gastropods, and appears to have accumulated in the neritic zone. Thus the Patriarch Formation represents a largely 'shelf' deposit on the flank of a 'relatively shallow, off-shore carbonate rise' (Cooper & Druce, 1975, p. 565).

A few rare and poorly preserved specimens occurring in the *R. hectori* assemblage are referred to *Hedinaspis* and *Charchaquia*. Cook & Taylor (1975), Taylor & Cook (1976) and Taylor (1976) commented on the occurrence of these genera in western North America. For the occurrence in the Hales Limestone of central Nevada they proposed that these genera occupied the continental slope environment. The environment inferred for the North American Franconian and Trempealeauan occurrences is thus different from that inferred here for the New Zealand Tremadocian (= Trepealeauan (in part) and Lower Canadian) occurrences.

4.c. Biogeography

In their analysis of Tremadocian faunas, Whittington & Hughes (1974, p. 216) placed Australia in their Tsinaniid Province, Nevada in their *Rasettia–Highgatella* Province and Tienshan in their Olenid–Ceratopygid Province. The obvious similarities between faunas described from Nevada (Taylor, 1976), central China (Kobayashi, 1971), Tienshan (Troedsson, 1937) and the *R. hectori* fauna of New Zealand from apparently different environments indicate that a completely satisfactory explanation of trilobite distribution is not yet available.

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EXPLANATION OF PLATES

Plate 1

(*a*)–(*l*) *Ruapyge hectori* (Reed). Patriarch Formation, New Zealand.

(*a*) Internal mould, VA147, V1963, ×2.

(*b*) Internal mould of eye, VA147, V1963, ×30 approx.

(*c*) Internal mould showing panderian processes, VA313, V1963, ×2.

(*d*) Latex cast of external surface and librigena, VA151, V1963, ×2.

(*e*) Internal mould of VA151 showing panderian processes, ×2.

(*f*) Latex cast of external surface of telescoped specimen showing prosopon and glabellar tubercle. VA148, V1963, ×2.

(*g*) Latex cast of almost complete juvenile, VA315, V1965, ×3.5.

(*h*) Latex cast of crushed cephalon and several thoracic segments showing prosopon and glabellar tubercle, VA152, V1963, ×3.

(*i*) Internal mould of librigena, VA189, V1965, ×2.

(*j*) Internal mould of librigena, VA326, V1965, ×2.

(*k*) Latex cast of external surface of pygidium, lectotype AR 667, ×3.

(*l*)–(*m*) ?*Ruapyge hectori* (Reed). Patriarch Formation, New Zealand.

(*l*) Latex cast of external surface, VA297, V1967, ×2.

(*m*) Internal mould of pygidium, VA327, V1968, ×2.

Plate 2. *Ruapyge hectori* (Reed). Patriarch Formation, New Zealand.

(*a*) Internal mould of cephalon and thoracic segment, VA153, V1963, ×3.5.

(*b*) Latex cast of external surface of cranidium, showing glabellar furrows and prosopon, VA191, V1963, ×3.

(*c*) Internal mould of cranidium, VA190, V1963, ×4.

(*d*) Latex cast of external surface of cranidium, VA 329, V1963, ×3.

(*e*) Latex cast of parietal surface of incomplete cranidium, VA154, V1964, ×3.

(*f*) Internal mould of incomplete specimen, VA 330, V1963, ×2.

(*g*) Enlargement of part of pygidium of (*f*), showing spacing of terrace lines, ×5.

(*h*) Latex cast of external surface of thorax and pygidium, VA160, V1963, ×2.

(*i*) Latex cast of external surface of pygidium, VA161, V1963, ×3.

(*j*) Latex cast of pygidium, VA159, V1963, ×2.

(*k*) Internal mould of pygidium, VA163, V1963, ×3.

(*l*) Internal mould of pygidium, VA162, V1963, ×3.

Geol. Mag. Vol. 116, 1979, Wright, Plates 1 and 2, between pages 364 and 365.

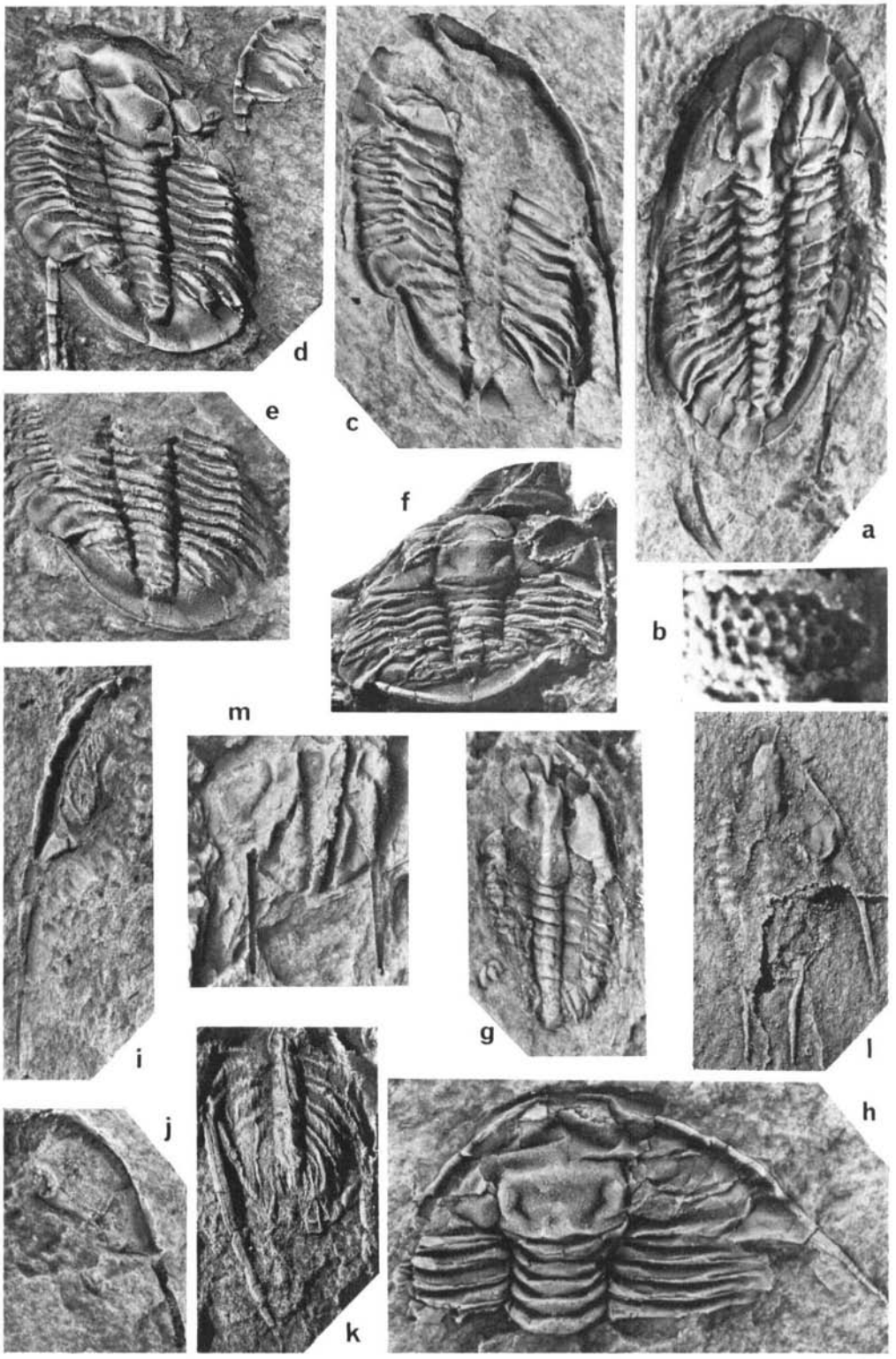

Plate 1. *Ruapyge hectori* (Reed). Patriarch Formation, New Zealand.

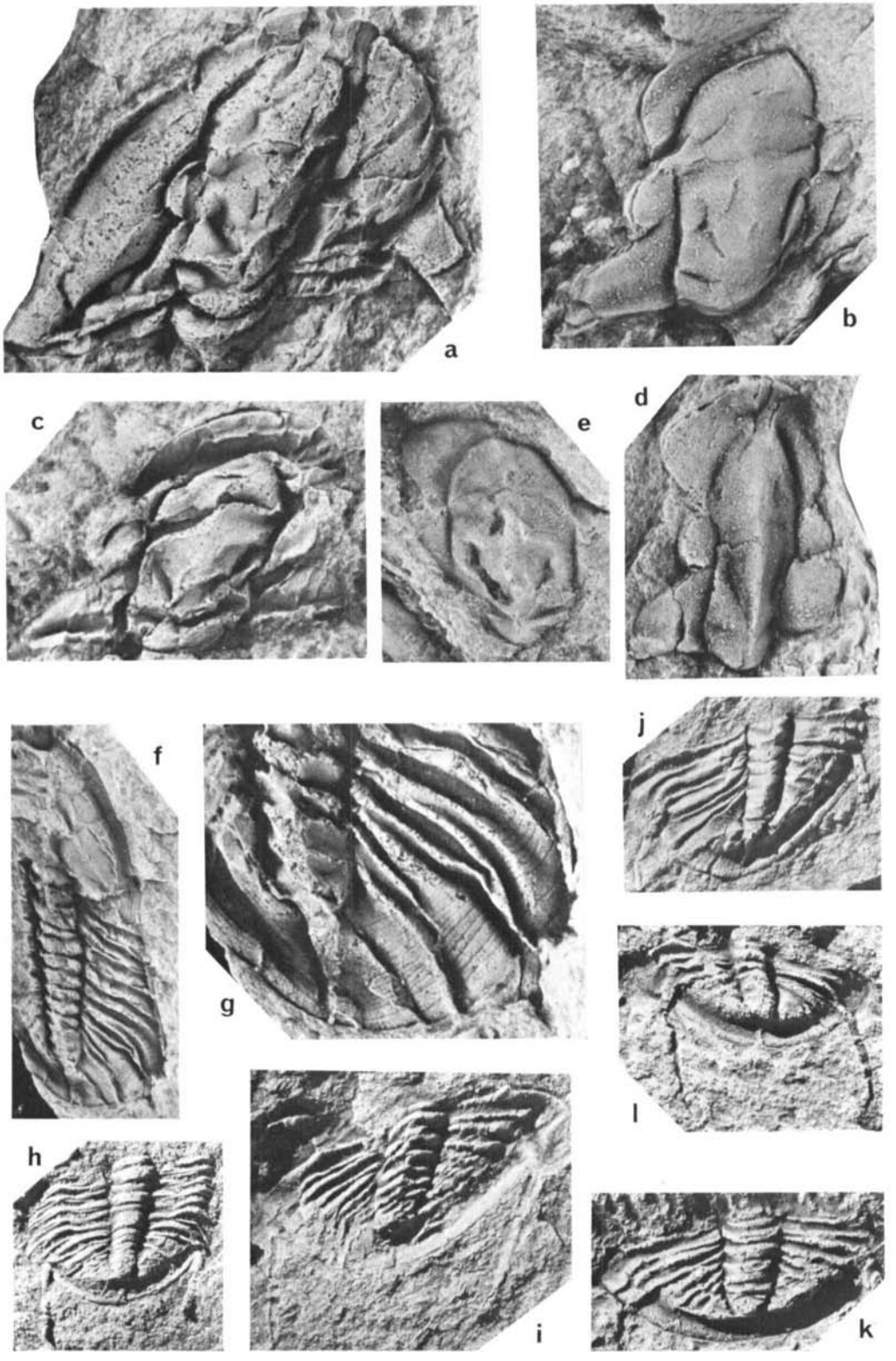

Plate 2. *Ruapyge hectori* (Reed). Patriarch Formation, New Zealand.